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[54] LOCK-UP CLUTCH PRESSURE CONTROL DEVICE

4,881,627 11/1989 Ishii 192/.076

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0260761 12/1985 Japan 192/3.3

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0084474 4/1986 Japan 192/3.3

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[57] ABSTRACT

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A spool of a lock-up control valve has a first effective area exposed to a release pressure which is supplied to a release chamber of the lock-up clutch and a second larger effective area which is exposed to the apply pressure which is supplied to an apply chamber. When acceleration is demanded when the lock-up clutch is in one of slip or fully lock-up modes and a sudden demand for acceleration is made, the pressure differential between the apply and release pressures is reduced below the normal level for a predetermined period of time.

[52] U.S. Cl. 192/.075; 192/3.3

[58] Field of Search 192/.075, .076, 3.3

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4 Claims, 5 Drawing Sheets

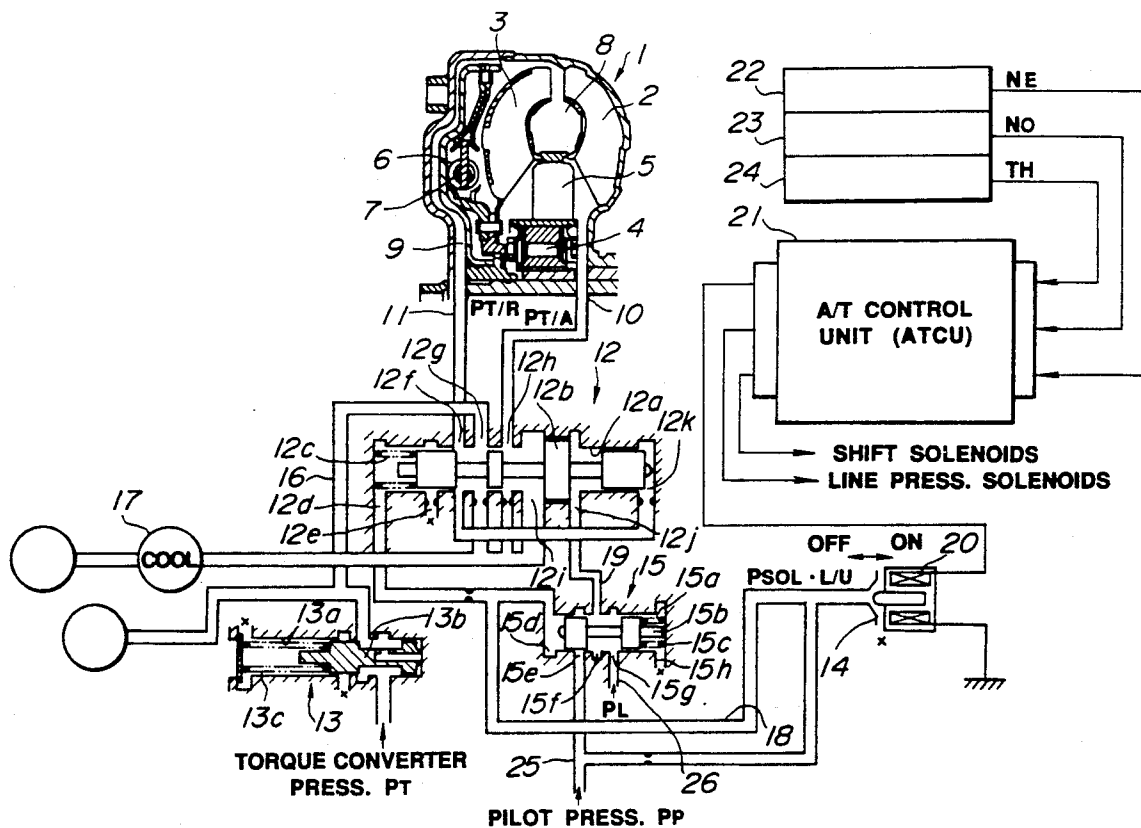


FIG. 2

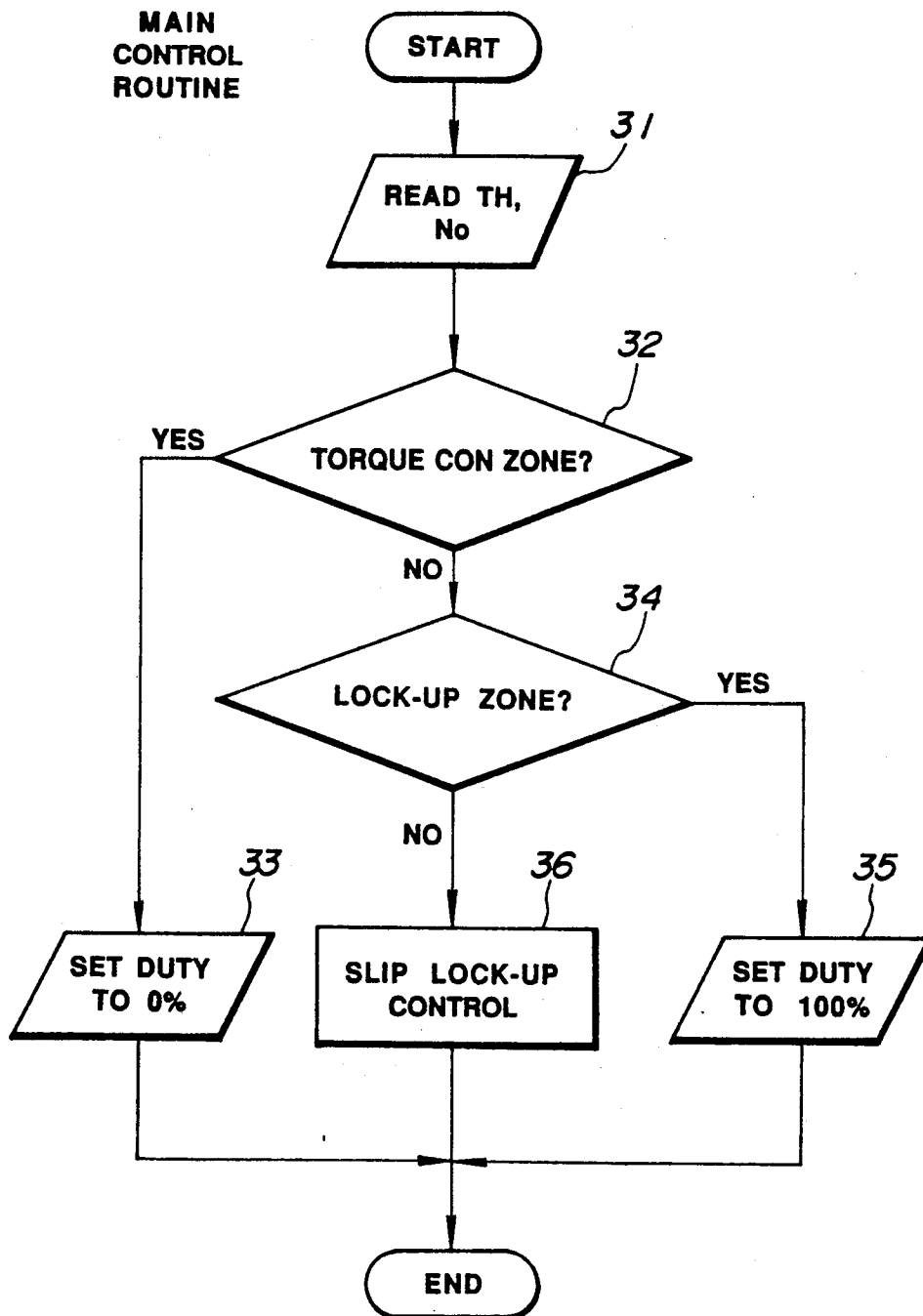


FIG. 3

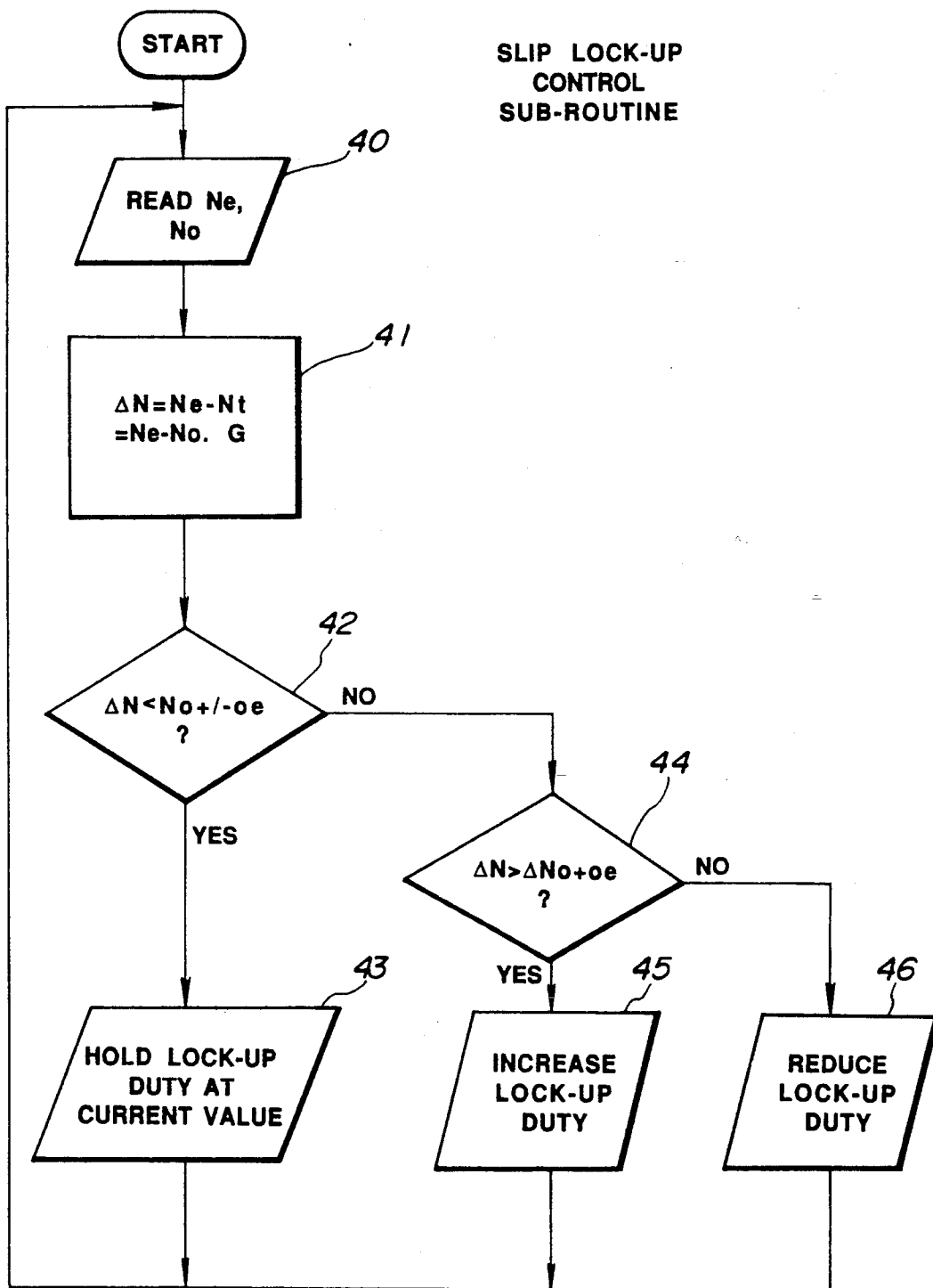


FIG. 4

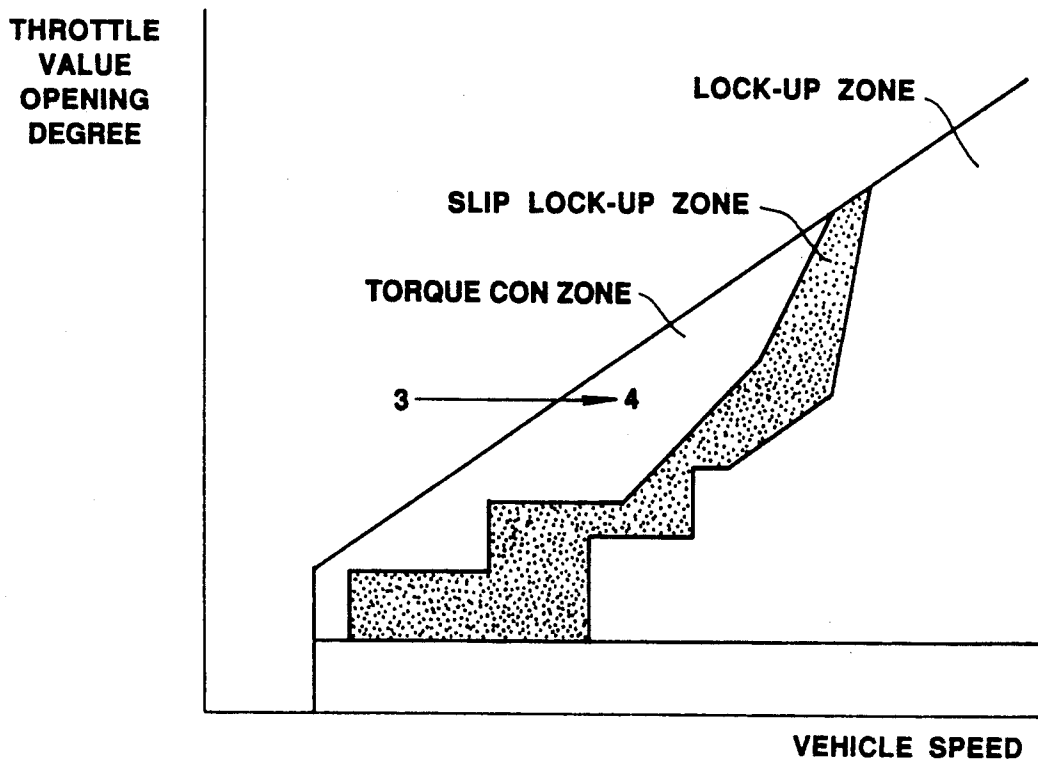
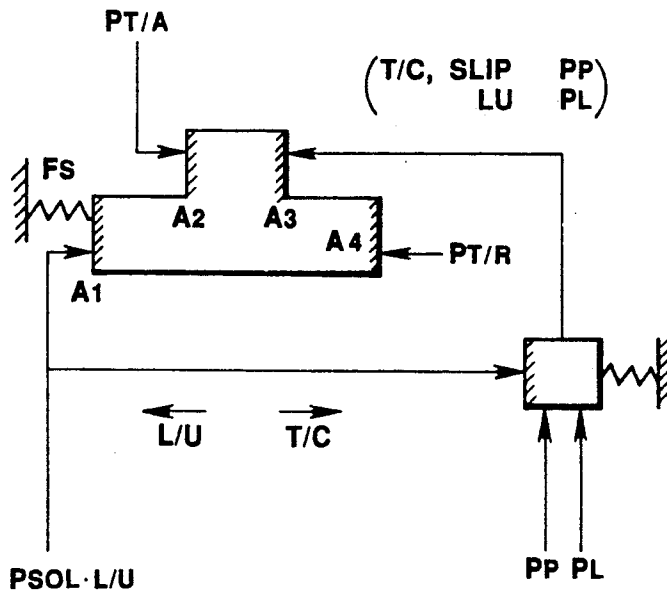
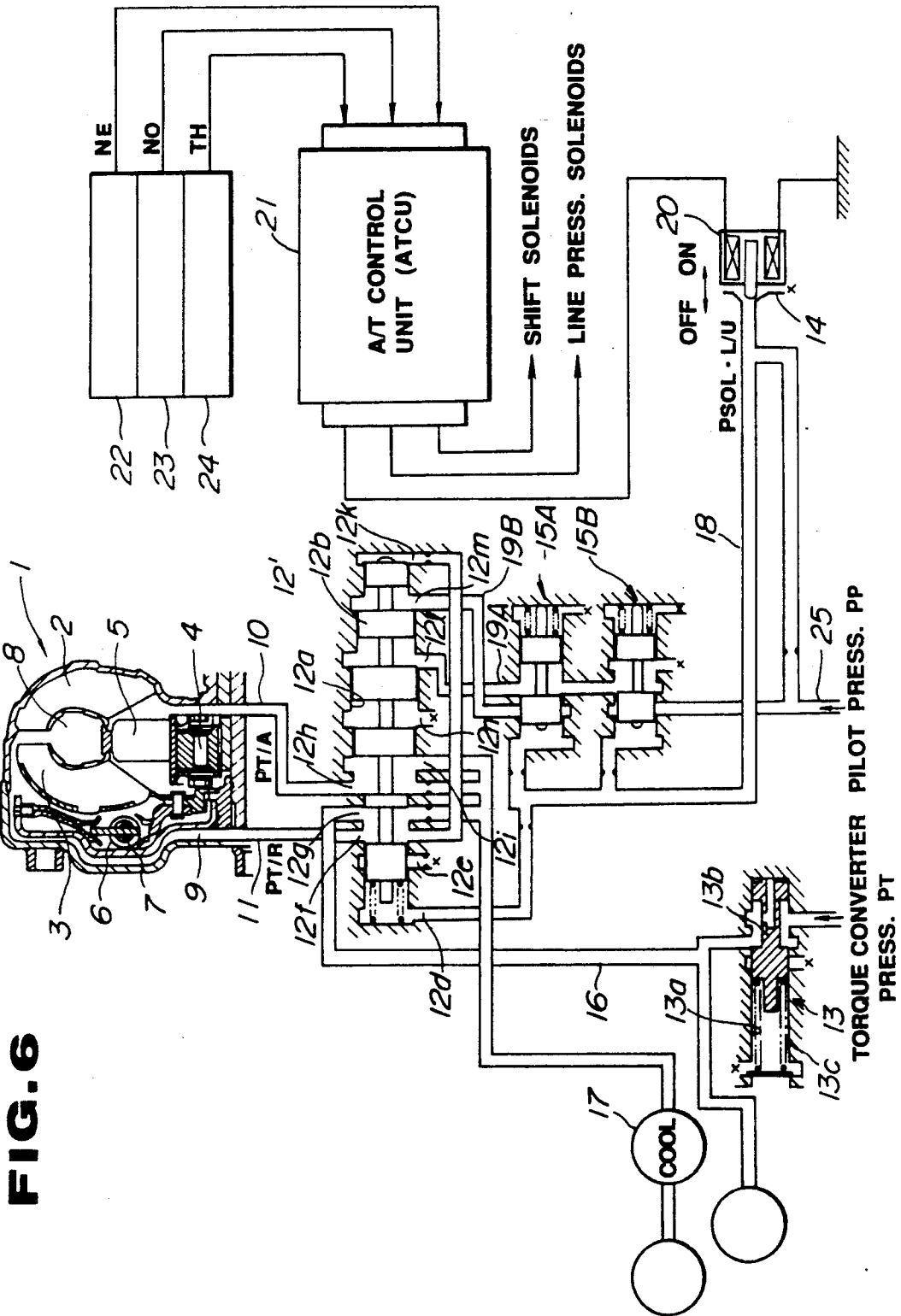


FIG. 5





LOCK-UP CLUTCH PRESSURE CONTROL DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to a hydraulic control system for an automatic automotive type transmission and more specifically to a lock-up clutch control arrangement for use with such a system.

2. Description of the Prior Art

JP-A-61-206868 discloses a lock-up control arrangement wherein engine load as indicated by engine throttle valve opening degree and vehicle speed are used to determine when a lock-up clutch should be fully released and induce a so-called open converter mode of operation, when the clutch should be partially engaged to induce what is referred to as slip lock-up and when the clutch should be strongly engaged to produce what shall be referred to as full lock-up.

However, with this type of arrangement, a drawback has been encountered in that during the slip or full lock-up modes of operation, if the accelerator pedal is subject to a sudden change in depression degree, the instant lock-up status is maintained until predetermined engine load/vehicle speed requirements are satisfied and the driver is unable to obtain the acceleration characteristics which would be expected for the given amount of pedal depression in response to the pedal depression.

That is to say, due to the load on the engine, when there is a delay between the actual change in throttle position induced by the accelerator pedal depression and the actual change in the engine speed.

In the case in which the solenoid valve which controls the lock-up is subject to electronic control, during slip or full lock-up modes of operation, it has been proposed that the rate at which the throttle opening changes be predetermined and if this rate exceeds a predetermined value, the lock-up clutch is conditioned to assume a fully released condition.

However, with this type of proposal, if a fail safe step is included, the control program is rendered undesirably complex and increases the production costs.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an improved lock-up control arrangement which simplifies the control arrangement, reduces production and maintenance costs, and exhibits suitable accelerator pedal depression/response characteristics without the need to resort to complex cost increasing control program software.

In brief, this object is achieved by an arrangement wherein a spool of a lock-up control valve has a first effective area exposed to a release pressure which is supplied to a release chamber of the lock-up clutch and a second larger effective area which is exposed to the apply pressure which is supplied to an apply chamber. When acceleration is demanded when the lock-up clutch is in one of the slip or fully locked-up modes and a sudden demand for acceleration is made, the pressure differential between the apply and release pressures is reduced below the normal level for a predetermined period of time.

More specifically, the present invention is provided in a transmission which features: an input element in a drive connection with a prime mover; and output ele-

ment in a drive connection with a gear train; a lock-up clutch operatively arranged between the input element and the output element, the lock-up clutch including an apply chamber in which an apply pressure is supplied and a release chamber in top which a release pressure is supplied, the lock-up clutch being responsive to the pressure differential which exists between the apply pressure and the release pressure in a manner to induce one of a released condition, a partially engaged condition, and a fully engaged condition; and pressure control means for controlling the pressure differential, the pressure control means including means for detecting a demand for acceleration and for reducing the pressure differential between the apply and release pressures below a normally required value for a predetermined time following the initiation of the acceleration demand.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a lock-up control arrangement according to a first embodiment of the present invention;

FIG. 2 is a flow chart depicting a main control routine which is used in connection with the control of the first embodiment;

FIG. 3 is a flow chart which depicts a slip lock-up sub routine which is run in connection with the present invention;

FIG. 4 is a graph showing the various operation zones in terms of engine load and vehicle speed;

FIG. 5 is a schematic diagram showing the concept used in connection with the lock-up control valve according to the present invention; and

FIG. 6 shows a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows a first embodiment of the present invention. In this arrangement, a torque converter 1 is operatively connected with a prime over such as an internal combustion engine (not shown) and includes a pump impeller 2 (input element); a turbine runner 3 (output element); a one way clutch 4; and a stator 5 which is operatively connected to a case by way of the one-way clutch 4. The pump impeller 2 and the turbine runner 3 are arranged to be selectively connected by a lock-up clutch 6. A clutch damper 7 which includes a torsion spring is operatively interposed between the turbine runner 3 and the lock-up clutch 6 in order to attenuate large torque fluctuations which tend to occur during lock-up.

The hydraulic control arrangement via which the lock-up clutch 6 is controlled is fluidly communicated with a lock-up clutch apply chamber 8 (hereinafter referred to as an "apply chamber") and a lock-up clutch "release chamber 9 (hereinafter referred to as a release chamber") of a thinly configured chamber arrangement, by way of apply pressure and release pressure conduits 10, 11. The conduit 10 transmits an apply pressure $P_{T/A}$ while conduit 11 transmits a release pressure $P_{T/R}$ from a lock-up control valve 12. The arrangement further includes a torque converter (T/C) relief valve 13 which regulates a basic pressure (P_T) to a predetermined maximum level; a lock-up solenoid valve 14 which modulates a supply of pilot pressure P_P to form a solenoid pressure $P_{SOL,LU}$ in response to an externally applied duty signal; and a switching valve 15 which is supplied with both pilot pressure P_P and line pressure

P_L and which supplies line pressure to the lock-up control valve 12 in place of pilot pressure when full lock up is required.

The lock-up control valve 12 controls the pressure levels which determine if the lock-up clutch is released, conditioned for slip lock-up, or conditioned to produce full lock-up. This valve comprises a bore 12a in which a spool 12b is reciprocally disposed and subject to a bias by a spring 12c. The bore is formed with ports 12d-12k. The spool is formed with an effective areas A_1 - A_4 which are respectively acted on by solenoid, converter, apply and release pressures.

In this arrangement, the area A_2 which is exposed to the apply pressure is larger than the area A_4 which is exposed to the release pressure, as seen also in FIG. 5.

The port 12d is supplied with solenoid pressure from the lock-up solenoid valve 14 via a conduit 18; the port 12e is used as a drain; the port 12g communicates with a torque converter pressure conduit 16; the port 12h communicates with the apply pressure conduit 10; the port 12i communicates with the oil cooler 17; the port 12j communicates with a switching pressure conduit 19 into which one of line pressure and pilot pressure are supplied.

The release valve 13 comprises a valve bore 13a in which a spool 13b and a spring 13c are disposed. As will be readily appreciated, when the bias produced by the torque converter pressure P_T exceeds that produced by the spring 13c, a drain port is opened to relieve the excess.

The lock-up solenoid valve 14 is arranged so that when the solenoid 20 is de-energized (OFF) the port 12d is supplied with pilot pressure P_P while when energized (ON), the port 12d is connected with a drain. Depending on the duty cycle of the signal applied to the solenoid 20, the level of solenoid pressure $P_{SOL/L/U}$ which is supplied to the port 12d is variable between the above mentioned limits.

The switching valve 15 comprises a bore 15a, a spool 15b and a spring 15c. The bore is formed with ports 15d-15h. The port 15d communicates with the solenoid pressure conduit 18, the port 15e communicates with a pilot pressure conduit 25, the port 15f communicates with the switching pressure conduit 19, the port 15g communicates with a line pressure conduit 26 and the port 15h acts as a drain.

The solenoid 20 is operatively connected with an A/T control circuit (ACTU) 21 which received data inputs from a plurality of sensors such as an engine speed sensor 22, a transmission output shaft rotational speed sensor 23 and a throttle valve position sensor 24. The outputs N_e , N_o and TH of these sensors are applied to the ACTU wherein they are processed (using a suitable program) in a manner to determine which mode of operation the lock-up clutch should be conditioned to produce. In accordance with this decision, the duty cycle of the signal applied to the solenoid is determined. For example, the schedule shown in FIG. 4 can be used to used following a 3-4 upshift to determine which mode of operation would be implemented and when. After the appropriate mode is ascertained, a suitable driver circuit can be induced to output a signal having a duty cycle which will induce the switching valve 13 to output the required pressure to the lock-up control valve 12.

It will be noted that the output of the throttle valve position sensor 24 can be monitored in a manner which reveals sudden changes in the vehicle acceleration

pedal depression degree and the rate at which the changes take place. OPERATION

FIG. 2 depicts in flow chart form, a main control routine which is used in connection with the control of the above described arrangement. FIG. 3 depicts a sub routine which is used to increase and decrease the duty cycle between the values for open and full lock-up mode of operation.

In connection with FIG. 2, the first step of the routine depicted therein such as to read in engine load and vehicle speed data. This can be achieved by sampling the outputs of the throttle valve position sensor 24 and the transmission output shaft rotational speed sensor 23. At step 32, this data is used to determine what lock-up clutch condition is required under the instant set of operating conditions. In other words, this step is such as to determine if a torque converter mode (no lock-up) is required or not. If no lock-up is required, then the routine flows to step 33 wherein a command to set the duty cycle to 0% is issued. This of course is such as to de-energize the solenoid (OFF) and thus induce the situation wherein full level pilot pressure P_P is supplied to the ports 12d and 15d.

On the other hand, if the outcome of step 32 is such as to indicate that a torque converter mode is not required, then the routine flows to step 34 wherein the instant engine speed and vehicle speed values are used in connection with mapped data of the nature shown in FIG. 4 to determine if the lock is required or not. In the event that full lock-up is indicated as being the appropriate mode of operation, the routine flows to step 35 wherein a command is made to raise the duty cycle of the signal applied to the solenoid to 100%. This of course induces the solenoid 20 to remain constantly energized and maintain the drain port of the valve 14 open. This reduces the pressure prevailing in ports 12d/15d to zero.

However, in the event that the need for full lock-up is not indicated, then the routine flows to step 36. In this step, the sub-routine shown in FIG. 3 is run. This routine supervises the control of the slip lock-up mode. The first step (40) of this sub-routine is such as to read in the engine speed N_e , engine load TH and vehicle speed (transmission output shaft rotational speed N_o). At step 41, the slip amount ΔN is derived using the following equations:

$$\begin{aligned}\Delta N &= N_e - N_t \\ &= N_e - N_o \times G\end{aligned}$$

where:

N_t denotes the rotational speed of the turbine; and
 G denotes the instant gear ratio.

At step 42, it is determined if the instant slip ratio ΔN is compared with a target slip ratio value ΔN_o . Depending on the outcome of this comparison the duty cycle is either incrementally increased or maintained at the instant value. That is to say, in the event that the value of ΔN is $\cong \Delta N_o + \epsilon - \epsilon$ then the routine flows to step 43 wherein a command to hold the duty cycle at its current value is issued. However, if ΔN is $> \Delta N_o + \epsilon$ then the routine goes to step 45 wherein a command to increase the duty cycle by a predetermined amount (by way of example) is issued. On the other hand, if $\Delta N < \Delta N_o - \epsilon$ then the routine goes to step 46 wherein a duty cycle reduction command is issued.

As will be appreciated, after one or more runs of the instant sub-routine the value of ΔN will be brought in the predetermined range of ΔN .

During slip and full lock-up modes of operation and acceleration is demanded, the engine torque is increased in response to the accelerator pedal depression along with the level of the line pressure P_L , the latter being increased to ensure that the friction elements of the transmission are adequately engaged.

Under these conditions, the prior art arrangement discussed previously is such that the apply pressure $P_{T/A}$ and the release pressure $P_{T/R}$ are adjusted via feedback control in a manner to increase the value of ΔP along with the engine torque and thus enable relative slippage in the lock-up clutch.

However, in this case if the slip lock-up or full lock-up mode is maintained irrespective of the driver having depressed the accelerator pedal in a manner which demands acceleration, the engagement of the clutch delays the required increase in engine speed and the resulting vehicle acceleration tends to be less than expected.

Thus, when the accelerator pedal is depressed, if the slip lock up mode of operation is currently being used the amount of slip is increased, or in the event of a full lock-up mode, the clutch is released for a fixed period of time.

In order to achieve the above, a basic feature of the present invention is to use a control valve other than the type which tends to reduce the ΔP value in response to an increase in line pressure and thus avoid the need to resort to special program software or changing the basic control program via which the value of ΔP is feedback controlled, to achieve the desired acceleration characteristics.

That is to say, as shown in FIG. 5, where slip lock-up conditions are induced the following relationship can be considered to exist

$$A_1 \times P_{SOLL/U} + A_2 \times P_{T/A} + F_S = A_3 \times P_P + A_4 \times P_{T/R}$$

$$P_{T/R} = \frac{1}{A_4} (A_1 \times P_{SOLL/U} + A_2 \times P_{T/A} + F_S - A_3 \times P_P)$$

Therefore the pressure differential ΔP is given by:

$$\Delta P = P_{T/A} - P_{T/R} = \frac{1}{A_2} \{ (A_4 - A_2) P_{T/A} + A_3 P_P - A_1 P_{SOLL/U} - F_S \}$$

However, P_P and F_S are fixed, accordingly:

$$\frac{A_3}{A_4} P_P - \frac{F_S}{A_4} = C \text{ (a constant)}$$

whereby

$$\Delta P = \frac{A_4 - A_2}{A_4} P_{T/A} - \frac{A_1}{A_4} P_{SOLL/U} + C \quad (1)$$

According to equation (1) if $(A_4 - A_2)/A_4 > 0$, then if the line pressure P_L level increases, the level of the apply pressure $P_{T/A}$ increases relatively and the value of ΔP also increases. On the other hand, if $(A_4 - A_2)/A_4 < 0$, in the event that the line pressure level increases, then the ΔP level decreases relatively. Further,

the value of $(A_4 - A_2)/A_4$ determined the amount by which ΔP changes.

Accordingly, while it is understood that setting $A_4 < A_2$ is preferred, a problem comes in the degree by which the ratio of A_4 to A_2 need be determined. Viz., if the difference is too big, then during open converter modes of operation when the accelerator pedal is returned, the ΔP value becomes excessively large and lock-up occurs while a ratio less than 0.5 is deemed appropriate.

In the instant embodiment, in view of the above, the apply pressure area A_2 is set to be larger than the release pressure area A_4 and thus establish the $(A_4 - A_2)/A_4 < 0$ relationship. Accordingly, if the accelerator pedal is depressed during either slip or full lock-up modes of operation, then the value of ΔP reduces with an increase in line pressure P_L and the amount of slip is increased or lock-up is released. This induces an improvement in acceleration characteristics.

After acceleration, when the accelerator pedal is returned to a cruising degree of depression, the level of line pressure P_L reduces and ΔP returns to its original value thus restoring the slip or full lock-up condition.

With the above arrangement the following merits are achieved:

[1] If the accelerator pedal is depressed at a rate which exceeds a predetermined value, while the lock-up clutch is conditioned to produce one of slip or full lock-up, the pressure differential ΔP which exists between the apply and release pressures $P_{T/A}$, $P_{T/R}$ is reduced below the level normally required for either the slip or full lock-up modes of operation for a predetermined period of time. As a result, good acceleration can be achieved even though the one of the slip or full lock-up modes of operation were employed at the time the acceleration was demanded.

[2] As the level of the line pressure is varied in response to the sensed accelerator pedal depression degree, the pressure differential areas of the lock-up control valve spool 12b are set so that when the line pressure increases the ΔP value decreases and there is no need to invest in expensive control program software. This reduces cost and eliminates the need for maintenance.

It will be appreciated that the construction and arrangement of the present invention is not limited to the above described embodiment and that various changes may be implemented without deviating from the scope of the same. For example, a second embodiment shown in FIG. 6 is such that the switching valve 15 is replaced with a full lock-up control valve 15A and a slip lock-up control valve 15B. The construction of the lock-up control valve 12' is modified in a manner wherein port 12j is replaced with ports 12i, 12m and 12n. In this case during open converter operation, neither conduits 19A, 19B are supplied with pilot pressure. On the other hand, when slip lock is required, only conduit 19A is pressurized, while in the case of full lock-up both are supplied with pilot pressure. This enables the same pressure to be applied to three different pressure responsive areas, one for each of the three modes of operation.

What is claimed is:

1. In a transmission
 - an input element in drive connection with a prime mover;
 - an output element in drive connection with a gear train;

a lock-up clutch operatively arranged between said input element and said output element, said lock-up clutch including an apply chamber in which an apply pressure is supplied and a release chamber into which a release pressure is supplied, said lock-up clutch being responsive to the pressure differential which exists between said apply pressure and said release pressure in a manner to induce one of a released condition, a partially engaged condition, and a fully engaged condition;

pressure control means for controlling the pressure differential, said pressure control means including means for detecting a demand for acceleration and for reducing the pressure differential between said apply and release pressures to a pressure below a normally required value for a predetermined period following the initiation of the acceleration demand; wherein said pressure control means comprises:

a lock-up clutch valve for controlling the supply of apply pressure to said apply chamber and the supply of release pressure to said release chamber, said lock-up clutch control valve including a spool, said spool having a first effective area against which said apply pressure acts and a second effective area against which said release pressure acts, said first effective area being larger than the second effective area and arranged to produce a bias which acts in a first direction when exposed to said apply pressure, said second effective area being arranged to produce a bias which acts in a second direction when exposed to said release pressure;

a solenoid valve for producing a first variable level control pressure; and

switching valve means, said switching valve means being responsive to the variable level pressure produced by said solenoid valve and arranged to sup-

ply a second control pressure to the lock-up clutch control valve; and

a source of line pressure and a source of constant level pilot pressure, said solenoid valve selectively reducing the pilot pressure to form said first variable level control pressure, said line pressure and said pilot pressure being supplied to said switching valve, said switching valve being arranged to be responsive to said first variable level control pressure in a manner wherein, when said first variable level control pressure is below a predetermined level said switching valve supplies pilot pressure to said lock-up control valve as said second control pressure and supplies line pressure to said lock-up control valve when the level of said first variable control pressure reaches said predetermined level.

2. A transmission as claimed in claim 1 further comprising a source of pilot pressure, said pilot pressure exhibiting a constant pressure level, said pilot pressure being supplied to said switching valve as a source of said second control pressure, and to said solenoid valve, said solenoid valve selectively reducing the pilot pressure to form said first variable level control pressure.

3. A transmission as claimed in claim 1 wherein said first variable level control pressure is supplied to said lock-up clutch control valve and used to produce a third bias which tends to move said spool in a first direction, and wherein said second control pressure which is supplied to said lock-up control valve tends to produce a fourth bias which acts in a direction opposite to that in which said third bias acts.

4. A transmission as claimed in claim 1 further comprising a source of torque converter pressure, said torque converter pressure source being fluidly communicated with said lock-up control valve and used as a source of said apply and release pressures, said torque converter pressure source being arranged to limit the level of said torque convert pressure to a predetermined maximum level.

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